# Solar Powered LED Street Lamps with Automatic On/Off System

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ABSTRACT
The suggested solar-powered LED street light system offers a budget-friendly and environmentally friendly option for lighting, as it harnesses renewable solar energy to operate continuously, even in remote locations. It incorporates automatic on/off control using ldrs and microcontrollers, By utilizing solar panels, LEDs, batteries, and smart control, the system provides a flexible and environmentally friendly solution for various lighting needs in different locations and public spaces.
**Keywords**: Solar Energy, LED Street Lighting, Renewable Energy, Light Dependent Resistor (LDR), Motion Sensor (PIR Sensor), Microcontroller (Arduino/ESP32), Smart Lighting Systems, Energy Efficiency, Sustainable Urban Infrastructure, Automatic Intensity Control.

## 1. INTRODUCTION

Street lighting plays a crucial role in urban development, ensuring safety and security for the community. Historically, street lamps have relied on electricity sourced from fossil fuel-based grids, resulting in substantial operational expenses and environmental issues. As the world becomes more urbanized and sustainability goals become increasingly important, alternative solutions are needed.Solar-powered street lamps have gained recognition as a promising solution. Solar energy, being plentiful and renewable, in conjunction with highly efficient leds, guarantees reduced reliance on traditional energy sources, decreased carbon emissions, and decreased maintenance expenses. Advanced lighting systems that incorporate microcontrollers and light- dependent resistors (ldrs) improve efficiency by automatically adjusting their operation based on the ambient light levels. The objective of this project is to create and implement a solar-powered street light system that adjusts its operation based on environmental lighting and traffic conditions, providing a smart and eco-friendly solution for contemporary infrastructure.

## 2. METHODOLOGY

The solar-powered street lighting system was created using a structured approach to guarantee energy efficiency, dependability, and automation. Traditional street lights that rely on the power grid consume a substantial amount of energy, require frequent maintenance, and contribute to environmental pollution. Remote regions encounter greater difficulties due to the absence of grid connectivity.

## 3. OBJECTIVES

- To design and develop an autonomous street lighting system powered entirely by solar energy, minimizing dependence on conventional electricity grids.
- To implement automatic switching of lights based on ambient light intensity using Light Dependent Resistors (LDRs).
- To ensure continuous operation during low- sunlight periods by incorporating reliable energy storage through lithium-ion batteries.
- To create a modular, scalable, and cost- effective system that can be deployed in various geographical and environmental conditions.
- To promote sustainable urban and rural infrastructure by integrating renewable energy and smart control

technologies.

## 4. DESIGN SPECIFICATION

### 1. Solar Panel:

**Type:** Monocrystalline Solar Panel
**Power Rating**: 150W
**Efficiency**: ~20–22%
**Voltage Output**: ~18V (at peak power)
**Description:**
Monocrystalline panels are made from a single continuous crystal structure.
They are known for: High efficiency, especially in limited spaces.
Better performance under low-light and cloudy conditions.
Long life span.

**Why Used:**

The 150W panel ensures enough power generation during the day to fully charge the battery, even in moderately sunny conditions.

### 2. Battery:

**Type:** Lithium-Ion Rechargeable Battery
**Rating:** 12V, 100Ah
**Energy Storage Capacity:** ~1200 W
**Description:**
Lithium-ion batteries are preferred because of: Higher energy density (stores more energy in less weight).
Deep cycle capability (80%–90% depth of discharge).
Longer life (up to 3000 charge cycles).
Faster charging and better efficiency compared to lead-acid batteries.

**Why Used:**
Stores solar energy collected during the day and powers the LED street light throughout the night — even during cloudy days (2–3 nights autonomy).

### 3. LED Fixtures:

**Type:** High-Lumen LED Street Light
**Power Rating:** 30W

**Luminous Efficacy:** ~130 lumens/watt **Description:** LED (Light Emitting Diode) fixtures offer: High brightness with minimal energy consumption.
Longer lifespan (around 50,000 hours). Low maintenance requirements.
Instant ON/OFF with no warm-up period. Why Used:
30W LED provides excellent street illumination with very low energy draw, making it perfect for solar-powered systems.

### 4. Microcontroller:

**Type:** Arduino Nano / ESP32 Board
**Operating Voltage:** 3.3V (ESP32)
**Memory:** 32KB Flash (Arduino) **Description:**
Microcontrollers handle

- Input from sensors (LDR, PIR).
- Processing decisions (when to switch ON/OFF, when to brighten/dim LEDs).
- Output to LEDs and battery management.
- Why Used:

Highly programmable, low-cost, low-power, easily integrates with various sensors and modules.

## 4.2 Testing:

- **Indoor Testing:** Simulated day-night transitions and motion activities to validate sensor functionality and switching logic.
- **Outdoor Testing:** Conducted over three months to assess system performance under real-world conditions such as rain, dust, and varying sunlight availability.
- **Performance Evaluation:** Monitored key parameters like energy savings, battery autonomy, sensor response times, and system durability.

### 4.3 Outcome:

The methodology successfully led to the development of an energy-efficient, autonomous solar street lighting system demonstrating over 70% energy savings, quick response to motion detection, and operational reliability even under adverse environmental conditions.

## 5. DESIGN AND CAD MODELING:

### 5.1 Part of solar lamp:

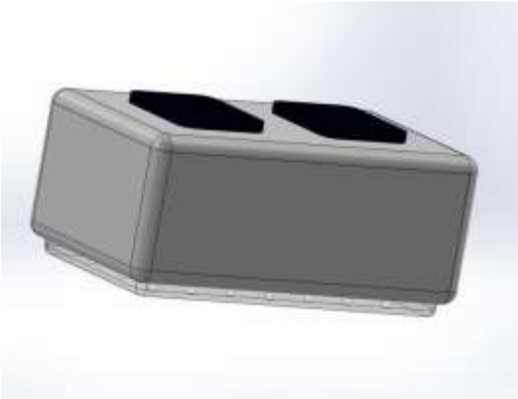


Fig.1 Solar lamp

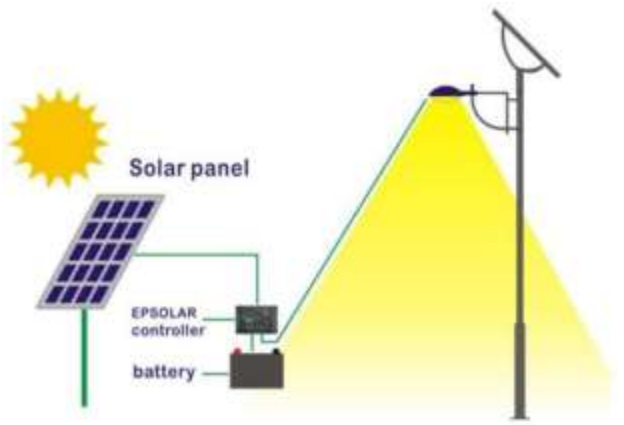
Fig. 2 Stand

### 5.2 Assembly of solar lamp:

Fig .3 Assembly of Solar Lamp

### 5.3 Working Principle

During daytime, the solar panel charges the battery via the charge controller. As night falls and the ambient light decreases below a threshold, the LDR signals the microcontroller to turn on the LED light. During low-traffic hours (e.g., midnight to early morning), the system reduces brightness to conserve energy. Upon detecting movement, the PIR sensor prompts the system to increase brightness to maximum for enhanced safety. The next morning, as ambient light increases, the microcontroller switches off the LEDs.




### 5.4 Design Considerations

- Optimum tilt angle of the solar panel for maximum solar radiation.
- Battery capacity designed for at least 2 days of autonomy (bad weather conditions).
- Weatherproofing for outdoor installation.
- Fail-safe switching mechanisms to prevent damage during sensor failures.

## 6. CALCULATION:

### 1. Solar Panel Sizing

- Energy required per day = 50W × 12h = 600 W/day
- Required panel size = 600 W ÷ (5h × 0.8) = 150W
- Final Selection: 150W monocrystalline solar panel.

### 2. Battery Sizing

- Battery capacity = (600 W × 2 days) ÷ (12V × 0.8) = 125Ah
- Final Selection: 12V, 125Ah lithium-ion battery.

### 3. LED Power Requirement

- Power = 1500 lumens ÷ 100 lumens/watt = 15W
- Final Selection: 15W LED for 1500 lumens output.

### 4. Charge Controller Sizing

- Solar panel current = 150W ÷ 12V = 12.5A
- Controller rating = 12.5A × 1.25 = 15.6A
- Final Selection: 16A charge controller.

**5. Wire Sizing**

- System current = 12.5A.
- Use 12-gauge copper wire to support up to 20A over 20 meters with minimal voltage drop.

**6. Inverter Sizing (if AC load required)**

- Inverter power = 50W ÷ 0.9 = 55.56W
- Final Selection: 60W inverter.

**7. Motion Sensor Range**

- Coverage radius required: 10 meters.
- Standard PIR sensors with 120° detection angle are sufficient.

## 7. ADVANTAGES AND APPLICATIONS

### 7.1 Advantages

- **Energy Independence:**

The system operates entirely on solar energy, eliminating reliance on conventional electricity grids. It is highly beneficial in remote locations where grid connectivity is unavailable or unreliable
.

- **Cost-Effective:**

After installation, operational and maintenance costs are minimal. Solar-powered systems drastically reduce electricity bills and maintenance frequency due to the longer lifespan of LEDs and lithium-ion batteries.

- **Environmentally Sustainable:**

The system generates zero operational emissions, significantly reducing the carbon footprint compared to grid-powered street lighting. It contributes directly to global efforts toward renewable energy adoption and climate change mitigation.

- **Scalability:**

The modular design allows easy expansion by adding additional solar panels, batteries, and lights. It can be scaled from a single light to an entire smart city network without major redesigns.

- **Safety Enhancement:**

Intelligent brightness control ensures brighter lighting in high-traffic or high-activity areas, improving visibility for pedestrians and vehicles while conserving energy during low-traffic periods. Motion-activated features enhance security and public safety.

### 7.2 Applications

- **National Highways and Expressways:** Provides reliable illumination across long stretches of roads without requiring costly grid infrastructure, improving nighttime driving safety.

- **Rural Electrification Projects:**
Offers an ideal solution for lighting in villages and remote regions where extending power lines is expensive or impractical.

- **University and Industrial Campuses:** Enhances campus safety, reduces energy costs, and supports institutions' sustainability goals through eco-friendly lighting solutions.

- **Parks and Public Recreational Zones:** Ensures safe access to recreational spaces after dark, creating secure and welcoming environments for public use with minimal environmental impact.
- **Disaster Relief and Emergency Lighting:** Rapidly deployable in disaster-hit areas to provide essential lighting without requiring grid connectivity, aiding rescue and rehabilitation efforts.

## 8. FUTURE SCOPE

Future improvements can include:
- AI-Based Predictive Maintenance: Monitoring system health and alerting for preventive actions.
- Self-Cleaning Solar Panels: Using vibration or hydrophobic coatings.
- Smart Integration: Incorporating features like Wi-Fi hotspots, CCTV cameras on poles.
- Energy Sharing Networks: Surplus solar energy feeding into microgrids or backup systems.

Advancements in sensor technologies and machine learning could revolutionize lighting to be fully autonomous, self-optimizing, and capable of peer- to-peer energy trading.

## 9. CONCLUSION

Cost Breakdown

1. Initial Investment:
Solar LED Lamp: ₹30,000 Traditional Lamp: ₹15,000

2. Operational Costs:
Annual Electricity Cost for Traditional Lamp: ₹15,000
Annual Maintenance Cost for Traditional Lamp: ₹5,000
Annual Maintenance Cost for Solar LED Lamp: ₹2,000

3. Lifespan: Both systems are assumed to last for 20 years.

Total Cost Calculation

Traditional Lamp Total Cost Over 20 Years: Initial Cost: ₹15,000
Electricity Cost: ₹3,00,000 Maintenance Cost: ₹1,00,000
Total: ₹4,15,000

Solar LED Lamp Total Cost Over 20 Years: Initial Cost: ₹30,000
Maintenance Cost: ₹40,000 Total: ₹70,000

Break-even Analysis

The break-even point occurs when total costs are equal.

After 5 Years:

Traditional Lamp:
Initial Cost: ₹15,000 Electricity Cost: ₹75,000 Maintenance Cost: ₹25,000
Total: ₹1,15,000

The solar-powered LED street lamp system proposed provides a highly sustainable, intelligent, and economically viable solution to meet the lighting requirements of the modern world. By incorporating renewable energy, automation, and adaptive lighting technologies, the system offers energy savings, enhanced public safety, and environmental advantages. As technology advances, incorporating IOT, AI, and smart city frameworks will further enhance the capabilities and resilience of public lighting infrastructures.

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